Paleontological Research, vol. 4, no. 4, pp. 255–260, December 30, 2000

New cephalopod material from the Bashkirian (Middle Carboniferous) of the Ichinotani Formation, Central Japan

SHUJI NIKO

Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University, Higashihiroshima, 739–8521, Japan (niko@hiroshima-u.ac.jp)

Received 5 June 2000; Revised manuscript accepted 23 August 2000

Abstract. **Three Bashkirian (Middle Carboniferous) species of orthocerid cephalopods, the orthoceratid *Hidamichelinoceras bandoi* gen. et sp. nov. and the pseudorthoceratids *Mooreoceras* sp. and *Adnatoceras ichinotaniense* Niko and Hamada, 1987, are described (or redescribed) from the Ichinotani Formation, Central Japan based on new material. The siphuncular structure of *Hidamichelinoceras* is shared with *Michelinoceras*, but this new genus is characterized by its broadly cone-shaped initial camera and rapid shell expansion. The discovery of *Mooreoceras*, which previously had been known only from the Hikoroichi Formation in Japan, supports a paleobiogeographic link between the Fukuji and southern Kitakami areas in the Carboniferous. The apical shell diagnosis of *Adnatoceras ichinotaniense* is added.**

Key words: **Bashkirian (Middle Carboniferous), *Hidamichelinoceras* gen. nov., Ichinotani Formation, Orthocerida.**

Introduction

Recent research on Far Eastern Carboniferous orthocerids and bactritids has shown that at least two isolated faunal provinces were present through the period in the area, i. e., the Taishaku-Akiyoshi-South China Province with the *Bogoslovskya* and *Bactrites* lineage (Niko *et al.*, 1987, 1991, 1995, 1997; Niko and Ozawa, 1997) and the southern Kitakami-Fukuji Province with the *Adnatoceras* lineage (Niko and Hamada, 1987; Niko, 1990). Nevertheless, our knowledge of Carboniferous orthoconic cephalopods is too limited to permit detailed paleobiogeographic reconstruction. Descriptive works are still critical also for providing phylogenetic information about these groups. As an additional account of orthocerid cephalopods in the Fukuji area, Central Japan, this work documents a new collection from the Bashkirian (Middle Carboniferous) limestone of the Ichinotani Formation. Details of the geologic setting and stratigraphic position of the collection have already been given by Niko and Hamada (1987).

The abbreviation UMUT for the repository stands for the University Museum of the University of Tokyo.

Systematic paleontology

Order Orthocerida Kuhn, 1940
Superfamily Orthocerataceae M'Coy, 1844
Family Orthoceratidae M'Coy, 1844
Subfamily Michelinoceratinae Flower, 1945
Genus ***Hidamichelinoceras*** gen. nov.

Type species.—*Hidamichelinoceras bandoi* sp. nov., by monotypy.

Diagnosis.—Orthoconic michelinoceratinid with rapid shell expansion, 9°–13° in angle, for subfamily, circular cross section, and probably endogastric early juvenile portion; shell surface ornamented by transverse lirae; initial camera broadly cone-shaped with rounded apex, shallow; early siphuncle central then becoming subcentral in position; septal necks very long and orthochoanitic, forming very wide septal foramen; cameral deposits weakly developed, episeptal-mural and hyposeptal; auxiliary deposits absent.

Etymology.—The generic name is derived from Hida, which is a historic provincial name of the type locality, and *Michelinoceras*.

Hidamichelinoceras bandoi sp. nov.

Figures 1.1–1.6, 2.1

Diagnosis.—Same as for the genus.

Description.—Based on single incomplete phragmocone of orthoconic shell with circular cross section; early juvenile shell indicates probable endogastric curvature; shell expansion rapid as for subfamily, its angle approximately 13° apically, then decreases to approximately 9° adorally; diameter of adoral shell attains 6.2 mm. Surface ornamentation consists of transverse and somewhat distant lirae forming weak sinuations. Sutures not observed, but obvious obliquity not recognized in dorsoventral section. Initial camera broadly cone-shaped with rounded apex, shallow and relatively small with 0.9 mm+ (slightly deformed) in maximum diameter and 0.3 mm in length between both apexes of initial and second camerae; cameral length abruptly increases in following camerae, then re-shortened adorally; maximum diameter/length ratios of adoral camerae range from 1.7 to 2.2; septal curvature moderate to relatively deep in seven apical septa, then becomes shallower in adoral septa. Siphuncular position nearly central in early juvenile shell, then slightly shifts in ventral direction, subcentral; minimum distance of central axis of siphuncle from shell surface versus shell diameter decreases to 0.4; caecum weakly inflated; siphuncle consists of orthochoanitic septal necks and nearly cylindrical connecting rings in second to seventh camerae; connecting rings missing in adoral camerae where septal necks are orthochoanitic, very long, 0.65–0.79 mm in length, attaining 0.3 in ratio of septal neck length/cameral length; diameters of septal necks are 0.61–0.71 mm; septal foramen cylindrical, very wide for subfamily, 0.52–0.63 mm in diameter; ratio of septal neck diameter to corresponding dorsoventral shell diameter attains 0.13. Cameral deposits weakly developed, restricted to apical 10 camerae, episeptal-mural and hyposeptal, slightly thicker in venter than dorsum; circumsiphuncular ridges of episeptal and hyposeptal deposits partly extend onto ventral side of connecting rings and septal necks, respectively. Endosiphuncular deposits, including auxiliary ones, are absent.

Discussion.—The siphuncular structure of *Hidamichelinoceras bandoi* gen. et sp. nov. suggests a close relationship to the widespread genus *Michelinoceras* (Foerste, 1932; type species *Orthoceras michelini* Barrande, 1866). The most important distinctive feature is the morphology of the initial camera. In contrast to the broadly cone-shaped initial camera of this new genus, the longitudinally elongated bulbous form of the type species of *Michelinoceras* was confirmed by Ristedt (1968, pl. 1, fig. 1). The rapid shell expansion (9°–13° in angle) of *Hidamichelinoceras* in comparison with the much slenderer shell shape of *Michelinoceras* (1°–2° in angle of shell expansion of *M. michelini*) is also regarded as enough to be of generic significance. *Hidamichelinoceras* differs from the Devonian to Carboniferous genus *Bogoslovskya* (Zhuravleva, 1978; type species, *B. perspicua* Zhuravleva, 1978) in having a less eccentric siphuncular position with a wider septal foramen and in lacking auxiliary deposits. The Triassic genus *Trematoceras* (Eichwald, 1851, not seen by the author; its generic diagnosis, including apical shell morphology, comes from citation by Schindewolf, 1933; type species, *Orthoceratites elegans* Münster, 1841) has a cone-shaped initial camera but the shape of the septal necks of *Hidamichelinoceras* is quite unlike that of *Trematoceras*, whose septal necks are very short and suborthochoanitic. In addition, the cameral deposits of *Trematoceras* are characterized by the prominent lamellae. The circular shell cross section of *Hidamichelinoceras* clearly separates it from the Devonian genus *Arkonoceras* (Flower, 1945; type species, *Orthoceras arkonense* Whiteaves, 1898), which has a much slenderer shell characterized by its subquadrangular cross section.

The Ordovician genus *Sinoceras* (Shimizu and Obata, 1935; type species, *Orthoceras chinense* Foord, 1888) was erroneously assigned to the Michelinoceratinae (e. g., Sweet, 1964) owing to its orthoconic shell shape and its *Michelinoceras*-like very long septal necks indicating orthochoanitic forms. However, the enveloping cameral-endosiphuncular deposits on the septal neck and on both the adoral and apical surfaces of the septum, recognized in the type species of *Sinoceras* in Woodward's (1856, pl. 6, fig. 1) illustration, undoubtedly place *Sinoceras* in the family Lituitidae within the order Tarphycerida.

Material examined and occurrence.—Holotype, UMUT PM 27849, 28.0 mm in length from the uppermost part of the Lower Member, Ichinotani Formation.

Etymology.—The specific name refers to the late Dr. Yuji Bando, in recognition of his contributions to the study of fossil cephalopods.

Superfamily Pseudorthoceratacea Flower and Caster, 1935
Family Pseudorthoceratidae Flower and Caster, 1935
Subfamily Pseudorthoceratinae Flower and Caster, 1935
Genus ***Mooreoceras*** Miller, Dunbar and Condra, 1933

Type species.—*Mooreoceras normale* Miller, Dunbar and Condra, 1933.

Mooreoceras sp.

Figures 1.7–1.9, 2.7

Description.—Orthoconic phragmocone with gradual shell expansion and dorsoventrally depressed, oval cross section; diameter of apical end is 5.2 mm in dorsoventral direction and 5.8 mm in lateral direction, giving a form ratio of approximately 1.1. Surface ornamentation absent. Sutures transverse, nearly straight, or strongly oblique in rare cases; septal curvature shallow. Cameral length moderate for genus, cameral ratios of maximum dorsoventral diameter/maximum length are 0.2–0.4. Siphuncle subcentral, consists of cyrtochoanitic septal necks and subcylindrical connecting rings whose inflation is weak for genus. Cameral deposits not detected. Endosiphuncular deposits form annulosiphonate rings.

Discussion.—Although this species is known from a single specimen of a probable juvenile shell judging from the relatively weak inflation of the connecting rings, the oval cross section of the shell, subcentral siphuncular position with the cyrtochoanitic septal necks, annulosiphonate rings formed of endosiphuncular deposits and the lack of cameral deposits warrant generic assignment to *Mooreoceras*. Unsuccessful attempts to make a well-oriented thin section preclude a specific determination.

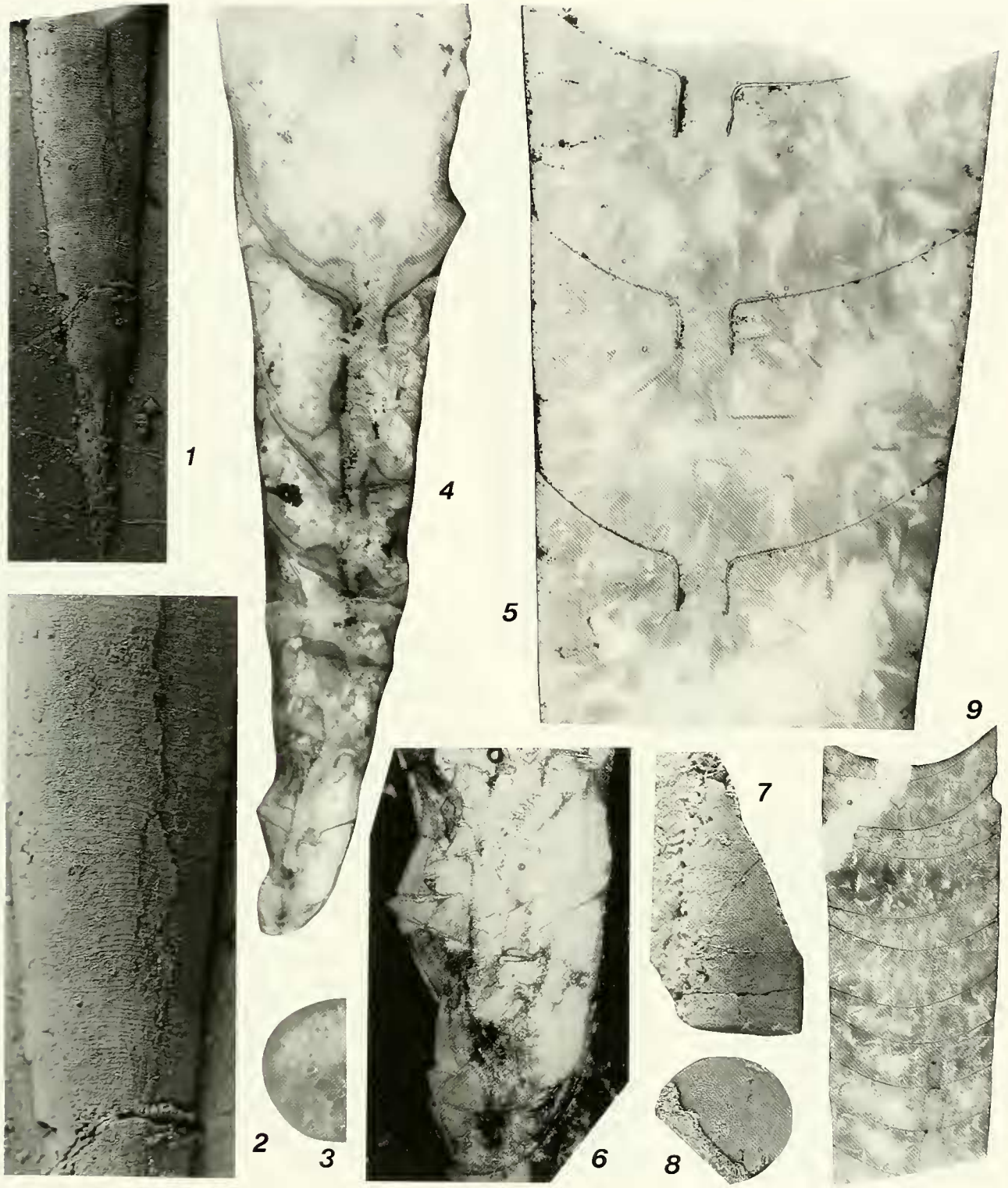

Figure 1. 1–6. *Hidamichelinoceras bandoi* gen. et sp. nov., holotype, UMUT PM 27849. **1**: Lateral view of silicone rubber cast, venter on right, ×4; **2**: Details of shell surface, showing ornamentation of transverse lirae, ×8; **3**: Polished cross section, venter down, ×4; **4**: Longitudinal thin section of apical shell, venter on left, slightly deformed, ×14; **5**: Longitudinal thin section of adoral shell, venter on left, ×14; **6**: Details of the three most apical camerae, note cone-shaped initial camera, ventral shell slightly deformed, ×30. **7–9**. *Mooreoceras* sp., UMUT PM 27850. **7**: Dorsal view, ×4; **8**: Septal view of apical end, venter down, ×4; **9**: Longitudinal thin section, venter on right, ×5.

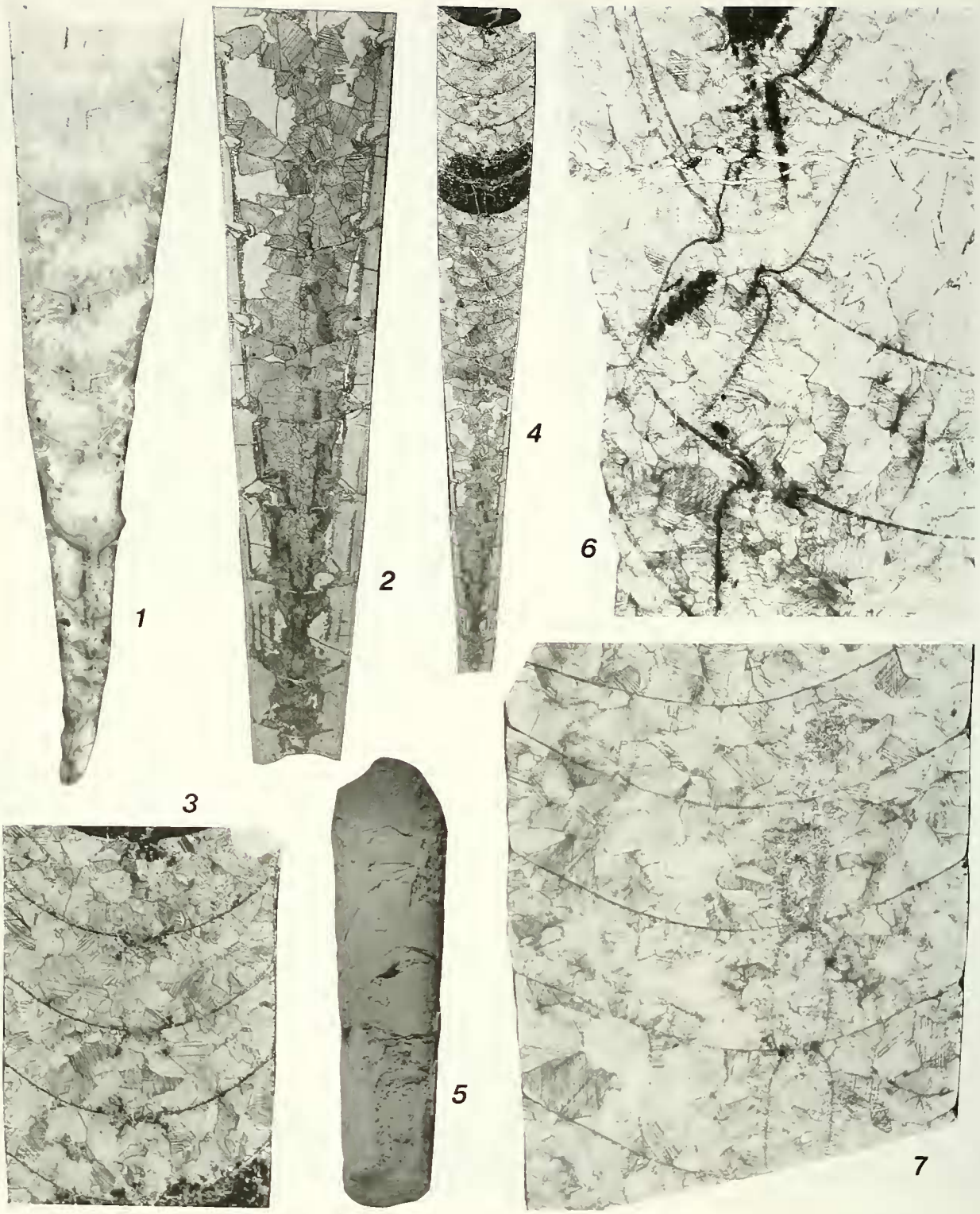

Figure 2. **1**. *Hidamichelinoceras bandoi* gen. et sp. nov., holotype, UMUT PM 27849, longitudinal thin section, venter on left, ×5. **2–6**. *Adnatoceras ichinotaniense* Niko and Hamada, 1987. **2–4**: UMUT PM 27852; **2**: Longitudinal thin section of apical shell, venter on right, ×14; **3**: Longitudinal thin section of adoral shell, venter on right, ×14; **4**: Longitudinal thin section, venter on right, ×5; **5**, **6**: UMUT PM 27851; **5**: Ventral view, ×2; **6**: Longitudinal thin section, details of adoral siphuncular structure, venter on left, ×14. **7**. *Mooreoceras* sp., UMUT PM 27850, longitudinal thin section, venter on right, showing siphuncular structure, ×14.

Previously, this genus had been represented in Japan solely by *Mooreoceras kinnoi* Niko, 1990, from the Visean (Early Carboniferous) of the Hikoroichi Formation in the southern Kitakami area, Northeast Japan. The present discovery of *Mooreoceras* sp. from the Fukuji area supports a paleobiogeographic link in the Carboniferous between the Fukuji and southern Kitakami areas, of which the similarity has also been suggested by the common occurrence of *Adnatoceras* in both areas.

Material examined and occurrence.—Single incomplete phragmocone, UMUT PM 27850, 15.0 mm in length. Stratigraphic horizon is identical with *Hidamichelinoceras bandoi*.

Subfamily Spyroceratinae Shimizu and Obata, 1935
Genus ***Adnatoceras*** Flower, 1939

Type species.—*Orthoceras spissum* Hall, 1879.

Adnatoceras ichinotaniense Niko and Hamada, 1987

Figure 2.2–2.6

Adnatoceras ichinotaniensis Niko and Hamada, 1987, p. 225, 227, figs. 3–1–6.

Adnatoceras ichinotaniense Niko and Hamada. Niko, 1990, p. 557; Kamiya and Niko, 1992, fig. 1–E.

Additional diagnosis.—Early siphuncle central in position with suborthochoanitic septal necks and cylindrical connecting rings. See Niko and Hamada (1987, p. 225) for diagnosis of adult shell.

Description.—Orthoconic shells with dorsoventrally depressed subcircular cross section up to nearly 4 mm in diameter and with a mean form ratio of approximately 1.1, then circular cross section attaining 9.1 mm in diameter; shell expansion moderate for genus, its angle approximately 4° in apical shell, then decreases to 2°–3° in adoral shell. Surface ornamentation absent; ventral wall slightly thicker than dorsal wall. Sutures straight, slightly oblique with approximately 5° to rectangular direction of shell axis, toward aperture on venter; septa relatively shallow; cameral length moderate to relatively short for genus; maximum width/length ratio of apical camerae ranges from 1.3 to 2.0, and ratio increases to 2.9–5.8 with 3.9 mean in adoral camerae. Early siphuncle central in position, composed of very short suborthochoanitic septal necks, 0.13 mm in length for a well-preserved one, and cylindrical connecting rings having weak constrictions at septal foramen; siphuncular position shifts towards a ventral one as shell grows, subcentral; ratio of minimum distance of central axis of the most adoral siphuncle from shell surface per shell diameter decreases to 0.3, where septal necks are asymmetrical, suborthochoanitic to cyrtochoanitic on dorsal side, with a length of 0.31 mm, and strongly recurved cyrtochoanitic on ventral side, with a length of 0.22 mm; adoral connecting rings subcylindrical, nearly parallel-sided and abruptly constricted at septal foramen; maximum diameter/length ratio of adoral siphuncle 0.5–0.7; adnation area very wide for family. Cameral deposits usually episeptal-mural and hyposeptal, but the latter are absent in some camerae, thicker in venter than dorsum. Endosiphuncular parietal deposits restricted on ventral siphuncular wall, thin, not fused. Adoral camerae lack both cameral and endosiphuncular deposits.

Discussion.—The description above is the same as in Niko and Hamada (1987) except that the apical shell morphology and most adoral siphuncular structures are added based on new specimens. The weaker cameral and endosiphuncular deposits of one specimen (UMUT PM 27852), compared to the holotype, probably result from its immaturity.

Material examined and occurrence.—Holotype, UMUT PM 18068; paratype, UMUT PM 18069. In addition, two newly collected incomplete phragmocones were examined: UMUT PM 27851, which includes more of the adoral shell than the type specimens, 38.3 mm in length, and UMUT PM 27852, which represents more of the apical shell than the type specimens, 23.0 mm in length. Stratigraphic horizon is identical with *Hidamichelinoceras bandoi*.

Acknowledgments

The author is grateful to Takashi Hamada for his helpful comments in the early stages of this study and to Hisayoshi Igo who provided locality information for the present cephalopods. Toshiaki Kamiya collected most of the specimens utilized in this study.

References

Barrande, J., 1866: *Système silurien du centre de la Boheme, Première Partie: Recherches paléontologiques. Volume 2, Classe des Mollusques, Ordre des Céphalopodes*, part 7, pls. 108–244, Praha.

Eichwald, E. von, 1851: Naturhistorische Bemerkungen, als Beitrag zur vergleichenden Geognosie, auf einer Reise durch die Eifel, Tyrol, Italien, Sizilien und Algier gesammelt. *Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou*, vol. 9, p. 1–464, pls. 1–4. (*not seen*)

Flower, R.H., 1939: Study of the Pseudorthoceratidae. *Palaeontographica Americana*, vol. 2, p. 1–214, pls. 1–9.

Flower, R.H., 1945: Classification of Devonian nautiloids. *American Midland Naturalist*, vol. 33, p. 675–724, pls. 1–5.

Flower, R.H. and Caster, K.E., 1935: The stratigraphy and paleontology of northeastern Pennsylvania. Part II: Paleontology. Section A: The cephalopod fauna of the Conewango Series of the Upper Devonian in New York and Pennsylvania. *Bulletins of American Paleontology*, vol. 22, p. 199–271.

Foerste, A.F., 1932: Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario (Part 1). *Denison University Bulletin, Journal of the Scientific Laboratories*, vol. 27, p. 47–136, pls. 7–37.

Foord, A.H., 1888: *Catalogue of the Fossil Cephalopoda of the British Museum (Natural History)*, part 1, 344 p., London.

Hall, J., *Palaeontology of New York. Volume 5, Descriptions of the Gastropoda, Pteropoda and Cephalopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups*, part 1, 492 p., part 2, 113 pls., New York Geological Survey, C. van Benthysen and Sons, Albany.

Kamiya, T. and Niko, S., 1992: Color markings on Devonian

orthochonic cephalopod from Fukuji, Gifu Prefecture. *Chigakukenkyu*, vol. 41, p. 149–153. (*in Japanese*)

Kuhn, O., 1940: *Paläozoologie in Tabellen*, 50 p. Fischer, Jena.

M'Coy, F., 1844: *A Synopsis of Characters of the Carboniferous Limestone Fossils of Ireland*, 274 p. Privately published. (reprinted by Williams and Norgate, London, 1862).

Miller, A.K., Dunbar, C.O. and Condra, G.E., 1933: The nautiloid cephalopods of the Pennsylvanian System in the Mid-Continent region. *Nebraska Geological Survey*, Bulletin 9, Second Series, p. 1–240, pls. 1–24.

Münster, G., 1841: *Beiträge zur Geognosie unt Petrefacten-Kunde des südöstlichen Tirols vorzüglich der Schichten von St. Cassian, Volume 4*, 152 p., 16 pls., Buchner, Bayreuth. (*not seen*)

Niko, S., 1990: Early Carboniferous (Viséan) cephalopods from the Hikoroichi Formation, southern Kitakami Mountains. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 159, p. 554–561.

Niko, S. and Hamada, T., 1987: *Adnatoceras* from Middle Carboniferous of the Ichinotani Formation, Fukuji district, Central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 148, p. 223–227.

Niko, S., Nishida, T. and Kyuma, Y., 1987: Middle Carboniferous Orthoceratidae and Pseudorthoceraceae (Mollusca: Cephalopoda) from the Akiyoshi Limestone, Yamaguchi Prefecture (Molluscan paleontology of the Akiyoshi Limestone Group-VIII). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 148, p. 335–345.

Niko, S., Nishida, T. and Kyuma, Y., 1991: Middle Carboniferous Bactrioidea (Mollusca: Cephalopoda) from the Akiyoshi Limestone Group, Yamaguchi Prefecture (Molluscan Paleontology of the Akiyoshi Limestone Group-X). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 161, p. 714–719.

Niko, S., Nishida, T. and Kyuma, Y., 1995: A new Carboniferous cephalopod *Bogoslovskya akiyoshiensis* from Southwest Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 179, p. 193–195.

Niko, S., Nishida, T. and Kyuma, Y., 1997: Moscovian (Carboniferous) orthoconic cephalopods from Guizhou and Guangxi, South China. *Paleontological Research*, vol. 1, p. 100–109.

Niko, S. and Ozawa, T., 1997: Late Gzhelian (Carboniferous) to early Asselian (Permian) non-ammonoid cephalopods from the Taishaku Limestone Group, Southwest Japan. *Paleontological Research*, vol. 1, p. 47–54.

Ristedt, H., 1968: Zur Revision der Orthoceratidae. *Abhandlungen der Mathematisch Naturwissenschaftlichen Klasse*, no. 4, p. 211–287, pls. 1–5.

Schindewolf, O.H., 1933: Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden. Eine Studie über Herkunft Stammesentwicklung und System der niederen Ammoneen. *Abhandlungen der Preussischen Geologischen Landesanstalt, Neue Folge*, no. 148, p. 1–115, pls. 1–4.

Shimizu, S. and Obata, T., 1935: New genera of Gotlandian and Ordovician nautiloids. *The Journal of the Shanghai Science Institute, Section 2, Geology, Palaeontology, Mineralogy and Petrology*, vol. 2, p. 1–10.

Sweet, W.C., 1964: Nautiloidea-Orthocerida. *In*, Moore, R.C. *ed.*, *Treatise on Invertebrate Paleontology*. p. K216–K261. The Geological Society of America and the University of Kansas Press.

Whiteaves, J.F., 1898: On some additional or imperfectly understood fossils from the Hamilton Formation of Ontario, with a revised list of the species therefrom. *Geological Survey of Canada, Contributions to Canadian Paleontology*, vol. 1, p. 361–427, pls. 48–50.

Woodward, S.P., 1856: On an *Orthoceras* from China. *The Quarterly Journal of the Geological Society of London*, vol. 12, p. 378–381, pl. 6.

Zhuravleva, F.A., 1978: Devonskiye ortoserodei, Nadotryad Orthoceratoidea (Devonian orthoceratids, superorder Orthoceratoidea). *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta*, vol. 168, 223 p. (*in Russian*)